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ANALYSIS OF INTER/INTRA SHIP MATERIEL MOVEMENT IN SEA BASED LOGISTICS USING SIMULATION

by

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Operational Maneuver From the Sea (OMFTS) and its implementing concept, Sea Based Logistics (SBL), stress the need for logistically supporting forces ashore directly from a sea base. This implies a radically different approach for supporting forces ashore in the future. This study analyzes the concept of SBL in the area of inter-ship and intra-ship movement of materiel as well as ship-to-objective materiel movement in order to gain insight into the envisioned SBL support concept. This study presents a conceptual model blending aspects of current underway replenishment (UNREP) processes with an operational scenario incorporating the tenets of the OMFTS and SBL concepts. A baseline simulation model was developed to estimate UNREP cycle times under various scenarios. Experiments were conducted by modifying the baseline model to assess the impact on inter/intra ship materiel movement cycle time by increasing the lift capacity of the helicopters used for vertical replenishment (VERTREP) as well as increasing the number helicopters used for VERTREP. Results indicate that an increase in helicopter lift capacity significantly reduce overall cycle time, more importantly UNREP cycle time. The simulation model identifies constraining resources (i.e., elevators and forklifts) that are on the critical path of operations. Results of this thesis will eventually help to configure the amphibious ships used for SBL in the future.

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ANALYSIS OF INTER/INTRA SHIP MATERIEL MOVEMENT IN SEA BASED LOGISTICS USING SIMULATION

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Operational Maneuver From the Sea (OMFTS) and its implementing concept, Sea Based Logistics (SBL), stress the need for logistically supporting forces ashore directly from a sea base. This implies a radically different approach for supporting forces ashore in the future. This study analyzes the concept of SBL in the area of inter-ship and intra-ship movement of materiel as well as ship-to-objective materiel movement in order to gain insight into the envisioned SBL support concept. This study presents a conceptual model blending aspects of current underway replenishment (UNREP) processes with an operational scenario incorporating the tenets of the OMFTS and SBL concepts. A baseline simulation model was developed to estimate UNREP cycle times under various scenarios. Experiments were conducted by modifying the baseline model to assess the impact on inter/intra ship materiel movement cycle time by increasing the lift capacity of the helicopters used for vertical replenishment (VERTREP) as well as increasing the number helicopters used for VERTREP. Results indicate that an increase in helicopter lift capacity significantly reduce overall cycle time, more importantly UNREP cycle time. The simulation model identifies constraining resources (i.e., elevators and forklifts) that are on the critical path of operations. Results of this thesis will eventually help to configure the amphibious ships used for SBL in the future.

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I. INTRODUCTION

No matter who carries the load in any fight. soldiers, sailors, airmen, or marines…they need to be supported and supplied from the sea.

-Admiral A. A. Burke, USN

A. BACKGROUND

The end of the Cold War has left the United States in a new global environment. This new environment is characterized by regional instability and greater uncertainty about new threats to our national security. The United States has been adjusting its national security strategy to meet the needs of this new environment. In 1992 the Navy and Marine Corps issued a white paper entitled *"from the Sea"* as its response to the new global environment. This announced a shift of strategy from traditional open-ocean fighting toward expeditionary operations conducted from the sea in the world's littoral regions. In 1994 a second white paper *"Forward...from the Sea"* further expanded the concepts of the original white paper. This stressed the role of naval expeditionary forces in peacetime operations, crisis response, and their role in regional conflicts. [Ref. 1]

The Marine Corps expanded the concepts delivered in these two white papers by developing a vision for future amphibious operations. They entitled this vision *Operational Maneuver from the Sea* (OMFTS) [Ref. 2]. OMFTS focuses on striking operational objectives directly from the sea. This departs from traditional amphibious doctrine that requires seizure of a beachhead and buildup of forces ashore prior to seizing an objective. The Sea Based Logistics (SBL) concept was developed to support OMFTS. [Ref. 3]

In addition the "*Maritime Prepositioning Force for the 21st Century (MPF Future (MPF (F))*" concept is being developed to replace the current MPF capability [Ref. 4]. The tenets of the Sea Based Logistics concept are being incorporated into the design of the MPF (F). These concepts stress the need to possess a capability to support operations ashore directly from the sea. This departs from the current practice of building combat service supports areas (CSSAs) ashore and from current MPF doctrine. Under this concept, MPF (F) ships would be able to support the Amphibious Task Force from the sea. No longer would a port and airfield be necessary to marry up the Marines and their equipment. [Ref. 4]

Currently ships are not designed to support forces ashore in the same manner that a CSSA can. Unlike a supply warehouse where clerks can access any item directly, our ships are loaded to utilize every square and cubic foot. Items are stowed in large containers that are loaded to optimize available space. Gaining access to specific items can be very difficult. Items are shuffled around in order to get to other items stowed deeper in the ship. The Sea Based Logistics concept strives to make all items available when needed. This implies that a radically different approach to ship design needs to be developed.

B. PURPOSE

This research will analyze the concept of Sea Based Logistics in the area of inter-ship and intra-ship movement of materiel. The purpose of this research is to provide insight that should be considered in the design of the future sea based logistics platform. The objective is to aid in future research and development by providing analysis of inter/intra ship materiel movement in the SBL concept.

C. SCOPE

This project focuses on the analysis of inter/intra ship materiel movement set against the backdrop of the OMFTS and SBL concepts. To accomplish this, we strive to answer the following questions:

- What is the impact of increased helicopter lift capacity on inter/intra ship materiel movement cycle time?
- What is the impact of increasing the number of helicopters conducting vertical replenishment on inter/intra ship materiel movement cycle time?

We first provide the reader an overview of the OMFTS, Ship To Objective Maneuver (STOM), SBL, and MPF (F) concepts. We then provide an overview of current methods of inter/intra ship materiel movement. Providing logistics support directly from the sea may require non-traditional ship designs in order to support these new concepts. In order to gain insight on what we will need in the future, we developed a baseline simulation model utilizing the Arena® simulation software, representing a way we could exercise the SBL concept with today's capabilities. Having created the baseline model, we vary the inputs through two scenarios. After analyzing the results, we provide conclusions and recommendations for further research into the design of the new sea based logistics platform.

D. METHODOLOGY

Research included: a detailed review of the OMFTS, STOM, SBL, and MPF (F) concepts, a review of current inter/intra ship materiel movement procedures and capabilities, familiarization with the Arena® simulation software package, development of a demand based operational scenario and simulation model, analysis of the simulation results, and providing recommendations for future platform capability.

Our research pertaining to the Sea Based Logistics concept was conducted through a literature search of books, research documents, doctrinal publications and other library information sources. Interviews with subject matter experts from both the military services and commercial sources provided experienced-based insight.

E. ORGANIZATION

This chapter provided the background, purpose, scope, and methodology of this study. The subsequent chapters are organized to follow the structure described in the scope and methodology mentioned above. The rest of this project is organized as follows:

II. OVERVIEW OF SEABASED LOGISTICS

III. SIMULATION MODEL DEVELOPMENT

IV. EXPERIMENTATION AND ANALYSIS

V. CONCLUSIONS AND RECOMMENDATIONS

II. BACKGROUND

> Completed in 1934, after years of intense study by Marine officers, *Tentative Landing Operations Manual,* broke ground for a new science in the realm of warfare, a means for carrying an assault from the sea directly into the teeth of the most strongly defended shore.
>
> \- General Holland M. Smith, USMC

A. INTRODUCTION

The way the United States has conducted warfare has changed continuously since the birth of our nation. New strategies and tactics have emerged with the development of new technologies, changing political climates and different global environments. Such was the case early in the 20^{th} century after the close of WWI. War with Japan loomed inevitable to some visionaries within the Marine Corps. The concept of Amphibious Warfare was developed to defeat the Japanese Empire. In 1934 the *Tentative Landing Operations Manual* was published. This publication, which was largely theory, was explored up until the war started with Japan in 1941. It laid the foundation for all amphibious operations conducted throughout WWII, from the Pacific Island campaigns to the beaches of North Africa and Europe. [Ref. 5]

The Marine Corps is once again facing a new world environment. Just as they did in the 1930's, the Marines are once again developing new concepts to counter the threats of the future. This chapter will explore these concepts. We first explain the operational concepts of OMFTS and STOM. We then focus on the concepts of SBL and MPF (F), and point out differences in our current capabilities and the capabilities of the future. We then provide an overview of our current inter/intra ship capabilities.

B. OPERATIONAL MANEUVER FROM THE SEA (OMFTS)

The Armed Forces of the United States, as they exist today, were primarily structured and equipped to counter the spreading threat of communism during the Cold War. With the collapse of the Soviet Union, the national security threats to the United States changed dramatically. The national security threats facing the United states today include: varying degrees of regional conflict and instability, the proliferation of weapons of mass destruction, and uncertainty about the future development of more powerful and direct threats to U.S. security. [Ref. 1]

In order to meet the national security needs emerging from this new global environment the Marine Corps developed OMFTS. OMFTS has been described as "the cornerstone of Marine Corps efforts to shape its fighting doctrine, forces and weapons systems of the future". [Ref. 1] OMFTS targets the littoral regions of the world as the likely venue for future conflict. "While representing a relatively small portion of the world's surface, littorals provide homes to over 80 percent of the worlds capital cities and nearly all of the marketplaces for international trade". [Ref. 2] OMFTS also stresses that the warfare of the near future will be characterized by its great variety. Thus preparing for only one type of conflict and focusing on a single threat only increases the danger that we will be defeated by another threat. [Ref. 2]

OMFTS merges the Marine Corps' Warfighting philosophy of Maneuver Warfare with Naval Warfare. OMFTS strives to exploit the ocean areas as maneuver space, in order to strike directly at operational objectives. This breaks from the current practice of first seizing and developing a beachhead prior to pushing out to strike operational objectives. In addition OMFTS:

- Generates overwhelming tempo
- Pits strengths against weakness
- Emphasizes intelligence, deceptions and flexibility
- Integrates all organic, joint and combined assets

It is envisioned that OMFTS will provide naval expeditionary forces great flexibility to respond to any crisis at any time, in any objective within the littoral regions. [Ref. 2]

C. SHIP TO OBJECTIVE MANEUVER (STOM)

One of the key implementing concepts for the goals established by OMFTS is STOM. While OMFTS states operational level goals, STOM is the tactical concept that applies "the principles and tactics to the littoral battle space" for conducting amphibious forcible entry. [Ref. 6]

STOM uses the concepts of maneuver warfare to exploit the advances made in mobility and command and control (C2) systems. Ship-to-shore movement and control during an amphibious assault is traditionally slow and methodical. STOM seeks to take advantage of emerging technologies to turn ship-to-shore movement into amphibious maneuver. The landing force would assault directly from the ship without necessarily establishing a beachhead ashore as depicted in Figure 1. [Ref. 6]

STOM's objective is to put the right sized units ashore, in their fighting formations, in a decisive place to accomplish the mission. Having the capability to operate from over the horizon (OTH), coupled with the ability to strike deep inland, STOM will force the enemy to defend a vastly larger area and provide the attacking forces with the element of tactical surprise. STOM uses the sea as a maneuver space. It emphasizes that the sea is "both a protective barrier and highway of unparalleled

mobility" [Ref. 6]. Having control of the sea allows the landing force to take advantage of the enemy's gaps by taking the axis of advance of their own choosing.

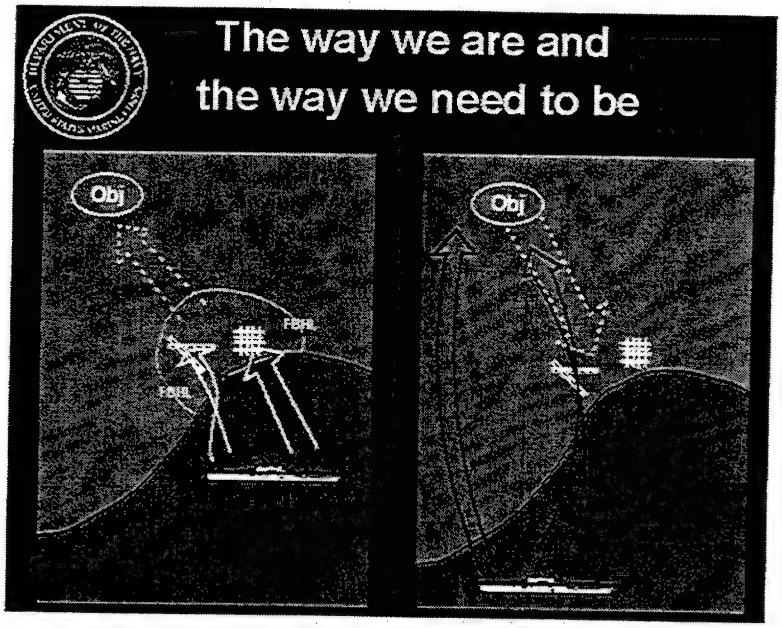

Figure 1. Ship to Objective Maneuver [From Ref. 6].

STOM dictates the rapid movement of combined arms teams ashore. However, it stresses that command and control, logistics and fire support remain sea based. Sea basing these three functions provides several advantages. The first advantage is a reduced footprint ashore. Advances in information connectivity will allow command and control, logistics, and fire support functions to be just as effective afloat as they are ashore today. Fewer personnel ashore translate to a reduced sustainment requirement for the total force ashore. Support will be focused to the combat units. Landing craft and vertical/short take-off and landing (VSTOL) aircraft that would have been used to transport the command element and logistics support ashore can now be utilized more effectively to support the combat units. A reduced footprint also increases the mobility of the combat units by freeing them from being tied to a beachhead. [Ref. 6]

A second advantage sea basing provides, is the decreased vulnerability of the command elements and support forces to enemy attack. Sea basing essentially eliminates the need for a large rear area security force. Without a rear area to protect, combat forces can focus on operations. This also takes away a lucrative target for the enemy. Ultimately STOM enables the landing force to project combat units that are leaner, lighter and more effective. [Ref. 6]

By striking objectives directly from the sea, the amphibious operation will terminate with the accomplishment of the mission vice the transfer of command and control ashore as in current doctrine. After accomplishing the mission the maneuver forces can either transition to subsequent operations ashore or re-embark to Amphibious Task Force (ATF) shipping to prepare for another operation.

There is an inherent challenge in providing logistics support to units operating under the STOM concept. Sea basing logistics support in effect makes our current logistics "push" techniques undesirable and infeasible. [Ref. 6] Units will have to operate under a logistics "pull" concept. They will need to have the ability to transmit their needs to the sea base, and the sea base will in turn supply them directly. This implies that a requirement for Total Asset Visibility (TAV) and the ability to selectively offload supplies. STOM envisions delivering tailored logistics packages directly to the supported unit. [Ref. 6]

D. SEA BASED LOGISTICS (SBL)

SBL is the implementing concept for logistics support in accordance with the OMFTS and STOM concepts. SBL outlines the requirement for operational and logistical support of forces operating ashore under the OMFTS and STOM concepts.

Having the ability to provide logistics functions directly from the sea base instead of from a cumbersome CSSA ashore will greatly reduce or eliminate the shore based logistics footprint associated with traditional amphibious operations. [Ref. 7] This provides the advantage of focusing on supporting the combat forces ashore without having the burden of providing rear area security (RAS) for the large amount of personnel and equipment associated with the CSSA. SBL also effectively eliminates the "iron mountain" of supplies currently required ashore to support of amphibious operations. SBL can also sustain the future high optempo battlefield and exploit the advantages of mobility and OTH standoff envisioned for in OMFTS.

Currently, limited sea basing is exercised in naval doctrine and practice. Moving to full sea basing will mean expanding on current practice and exploit emerging technology to be able to meet future tactical and operational sustainment needs. [Ref. 1] Key to this is the ability to provide "in stride sustainment". This will require merging ship-to-objective distribution with a network based automated logistics information system.

SBL requires the ability to perform the following five functions of logistics: supply and sustainment, transportation and distribution, maintenance, engineering and health service support. These functional areas today are performed both ashore and from ships. SBL requires them all to have the ability to be performed while sea based. Incorporating these functions with the tenets of SBL described below provides a great advantage to naval expeditionary forces. SBL requires implementing these five fundamental tenets into our operating procedures to provide sustainment. These are listed and explained below.

1. Primacy of the Sea Base

The primacy of the sea base will be its ability to build, project and sustain combat power. It will integrate all logistics functions aboard the sea based logistics platform. The sea base is envisioned to possess the ability to provide all combat service support functions afloat instead of ashore as in current practice. It will be able to provide indefinite support, serving as a floating workshop and distribution center. With the reduced logistical footprint ashore, much of the double handling of equipment and supplies that occurs today in a CSSA ashore will be eliminated. Under this concept maneuver units will have mobile combat service support units integral to them. They will carry their initial support requirements and the sea base will sustain them indefinitely by surface or by air as necessary. The sea base will then be replenished directly from sources in the continental United States (CONUS) or from around the world. SBL also frees the amphibious force from basing rights and host nation support. Sustaining an operation from the sea, gives naval expeditionary greater flexibility in conducting operations. [Ref. 3]

2. Reduced Demand

SBL aims to achieve higher levels of support through reduced demand on transportation and materiel resources. With improvements in operating efficiencies, reliability of equipment, precision ordnance and targeting, improved and alternate fuel efficiencies, demands for sustainment should be reduced ashore. Improved information technology can replace mass (the iron mountain ashore) with speed and information. This allows sustainment to be routed directly to the end user eliminating the need for the CSSA ashore to act as the middleman.

Demand will also be reduced by the very nature of OMFTS. Sea basing the elements of the landing force mentioned previously reduces the footprint of forces ashore, thus reducing sustainment requirements. Furthermore consolidating supplies aboard the sea base allows the amphibious force to carry fewer inventories. [Ref. 3]

3. In-Stride Sustainment

Automated requisition and distribution management systems will reduce costs, accelerate materiel movement and reduce redundant handling of materiel. Implementing a logistics "pull" system will enable logistics managers to take a management-by-exception approach. The requesting unit will request generated demand only from what they need, freeing the supporting unit from educated guesses on what demand is. This technique will eliminate the need for large quantities of materiel, which may not be needed, being moved and staged ashore. The ability to sustain highly mobile forces ashore from the sea base at any time greatly enhances the combat power and flexibility of these units. Additionally it provides commanders greater flexibility in planning and managing their resources ashore.

SBL requires an inherent selective offload capability. The ability to rapidly provide tailored logistics packages aboard the SBL platform is necessary. [Ref. 1] These packages will be built aboard the platform and transported via surface or aerial means directly to the requesting unit. Currently naval expeditionary forces have a very limited capability to do this, due to the design of our amphibious ships. The Combat Service Support Element (CSSE) currently performs the majority of this function ashore. SBL requires the CSSE to perform the majority of this function from the sea base platform. Implied in this task is the need to design a platform capable of doing this. [Ref. 3]

4. Adaptive Response and Joint Operations

SBL envisions the capability to integrate with theater logistics resources. Adaptability to dynamic operational requirements is necessary. SBL needs to support a wide spectrum of military operations, from forcible entry to disaster relief. Some operations may not initially have a port or airfield available. Once a port and/or airfield are secured, SBL will have the capability to transition part or all of its combat Service Support (CSS) functions ashore. This allows the Joint force Commander (JFC) greater flexibility in planning. Once follow-on forces arrive, the amphibious force can initially support them from the sea base. [Ref. 3]

5. Force Closure and Reconstitution at Sea

SBL allows forces to convene and assemble enroute to an objective. The key to this process is the physical merging of personnel and their equipment at sea. Assembling at sea eliminates the need for a secure port and airfield to accomplish this task. Combat power can be built-up at sea prior to engaging in combat. In the past, forces may have been required to seize a port and/or airfield prior to the arrival of the main force. This may have required engaging enemy forces. SBL eliminates this step. In turn, it gives the naval expeditionary force a greater element of tactical surprise since it limits your enemy's knowledge of the exact time and place of your landing and denying him the time to prepare for it. As follow on forces arrive in theater, SBL can support the force closure of joint and coalition forces. [Ref. 3]

The ability to reconstitute at sea, as needed, is also a combat multiplier. The JFC will gain additional flexibility for dealing with emerging situations. The ability to pull forces from one objective ashore, bring them back to the sea base to reconstitute them, and re-deploy them can be extremely advantageous to the commander.

The sea base will have a strategic pipeline to CONUS and other sources of supply. Rapid replenishment of the sea base directly from these sources without an interruption of operations ashore is a valuable asset to the commander. The sea base possesses an intermediate level of maintenance for its organic equipment. Equipment requiring depot level repair will be returned to CONUS or an intermediate staging area. These functions today are done by the CSSE ashore. Sea basing them reduces the logistic footprint ashore, gaining the advantages mentioned previously. [Ref. 3]

E. MARITME PRE-POSITIONED FORCE (FUTURE) (MPF (F))

MPF (F) is the concept, that requires the future generation of MPF's to contribute to forward presence and power projection. MPF (F) is envisioned to integrate and compliment the concepts of OMFTS and Sea based logistics. MPF (F) will be an integral part of SBL. The development of the next generation of MPF ships will incorporate the tenets of SBL. This is significant because the design of these ships will influence the design of the future SBL platform. [Ref. 4]

Currently, there are three MPF squadrons that can each support a Marine Expeditionary Brigade (MEB). Each squadron contains enough materiel and equipment to sustain a Marine Expeditionary Force (MEF) of approximately 19,000 marines and sailors for 30 days. MPF can rapidly deploy a Marine Air Ground Task Force (MAGTF) through a combination of Strategic Airlift and forward deployed Maritime Prepositioning Ships. An airfield and secure port is necessary for the force closure of the MAGTF. Enhancements have been added to the MPF and will include an Expeditionary Airfield, a Navel Mobile Construction Battalion, a Fleet Field hospital and additional equipment and sustainment. While the MPF today can conduct in-stream offloading and limited combat loading, a larger capability will be required for OMFTS. [Ref. 3]

Future MPF operations are based on the following pillars:

- *Force Closure.* MPF will provide for the at-sea arrival and assemble of the MPF. This eliminates the need to secure a port and airfield. The force will be prepared for operations when they arrive in the objective area.
- *Amphibious task force integration.* MPF ships will integrate with the ATF as depicted in Figure 2 to further enhance the combat power of the ATF. Multi-purpose in nature the ships will be able to assume tactical roles. They will possess lighterage that can operate in sea state three. This will be accomplished on its own or through the sea base.
- *Redeployment and reconstitution.* MPF will conduct in-theater replenishment. This gives it the ability to rapidly move to follow-on missions.

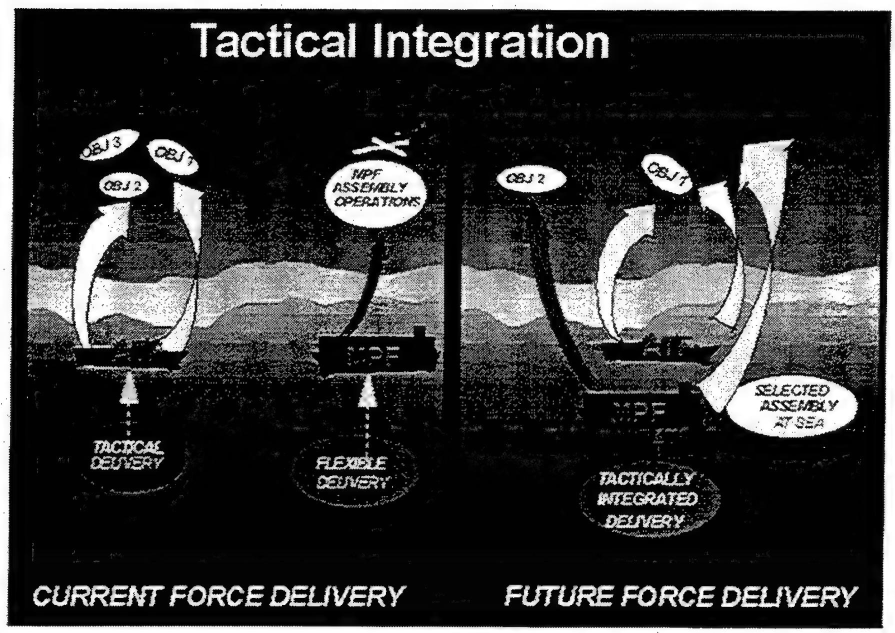

Figure 2. ATF Integration [From Ref. 4].

Like SBL, MPF (F) offers inherent force protection and the ability to exploit the sea as a maneuver space. It provides fast deployment and reinforcement capabilities to the MAGTF. It offers great flexibility to commanders. It also provides an opportunity to experiment with technologies and techniques that can be incorporated into the sea base platform of the future. [Ref. 4]

F. CURRENT INTER/INTRA SHIP MATERIEL MOVEMENT

Implied in the previously described concepts is the need for a platform designed to facilitate the rapid transfer of materiel. Currently amphibious ships are not designed to support the types of logistics operations envisioned in SBL. Our ships were designed to maximize stowage capability and facilitate the combat offloading of equipment and supplies. They were designed for offload by slow moving landing craft and aircraft in relative proximity to the shore. Dedicated staging areas for breaking down incoming supplies and repackaging them for distribution do not exist [Ref. 8]. Storage areas aboard these ships are largely inaccessible while the ship is fully loaded, without major re-arrangement. Movement within the ship is restricted to narrow fire lanes barely wide enough for materiel handling equipment (MHE). [Ref. 9]

Underway replenishment (UNREP) is most commonly accomplished by either connected replenishment (CONREP) or by vertical replenishment (VERTREP). Landing craft or ships boats can also be used to re-supply via surface. The most common form of UNREP for amphibious ships is by VERTREP [Ref. 10]. Material is slung in cargo nets under a helicopter from ship to ship. This procedure takes time, while the pilots hover and personnel connect the nets to the airplane. They then fly to and from the supporting and supported ships. [Ref. 10]

Typically when supplies are received, they arrive on pallets built to maximize space. These are brought aboard and large working parties of sailors and marines break them down by hand and deliver them throughout the ship. If the pallets are destined for cargo holds, forklifts move them to elevators or their final destination. Since the ships are loaded to capacity, storage for the new supplies is difficult to find. Material is either

moved by hand or brought closer to its final destination by materiel handling equipment (MHE), and then moved by hand. Many cargoes are further restricted by regulations due to their hazardous nature.

Currently, because of the nature of combat loading, inventories of supplies are not easily accessible. Ships are not loaded like supply warehouses. Inventory is jammed into embark boxes, containers and anywhere one can find room. Much care is placed into asset visibility, but due to the lack of space, asset visibility can erode as time passes.

All methods of replenishment are greatly affected by the sea state. If it gets too rough, UNREP operations can shut down. [Ref. 9]

G. CHAPTER SUMMARY

In this chapter we have examined the future Warfighting concept of OMFTS. We then examined the tactical implementation of this concept in STOM. In order to make OMFTS a reality, OMFTS must be supportable. SBL is the concept envisioned to do this. Next we examined the concept of MPF (F). Implied from these concepts is a need for sea-based platform that can accomplish the goals set out in SBL. A radically new approach to ship design is required. We finally explored some of the limitations of current amphibious ship design. The following chapters will generate some specific mission requirements to be considered for the design of the sea base platform.

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III. SIMULATION MODEL DEVELOPMENT

A. INTRODUCTION

A simulation model provides the means to replicate a system or process over a period of time normally through a computer with simulation software. Since computing power has become relatively inexpensive, a computer simulation is an extremely powerful tool to experiment with existing or future systems without expending the resources required for an experiment with the physical system. This rings especially true given the constrained resources present in today's military environment. Simulation allows developers to gain insight into a system's performance prior to actually building the physical system. [Ref. 11]

This chapter incorporates a simulation model representing aspects of the current UNREP process blended into an operational scenario that has the landing force operating under the tenets of the OMFTS and SBL concepts developed in Chapter II. We will present the background scenario for the model, our modeling approach and a detailed description of our methodology in translating the model into simulation logic using the commercially available ARENA® simulation software.

B. SCENARIO

A Marine Expeditionary Unit (MEU) sized MAGTF (1,500 personnel) has been conducting operations ashore for 7 days. They anticipate this operation to last another 7-10 days. The landing force consists of the GCE and a Mobile Combat Service Support Detachment (MCSSD) from the MEU Service Support Group (MSSG) in direct support. The Ground Combat Element (GCE) is operating five to ten miles inland as depicted in Figure 3.

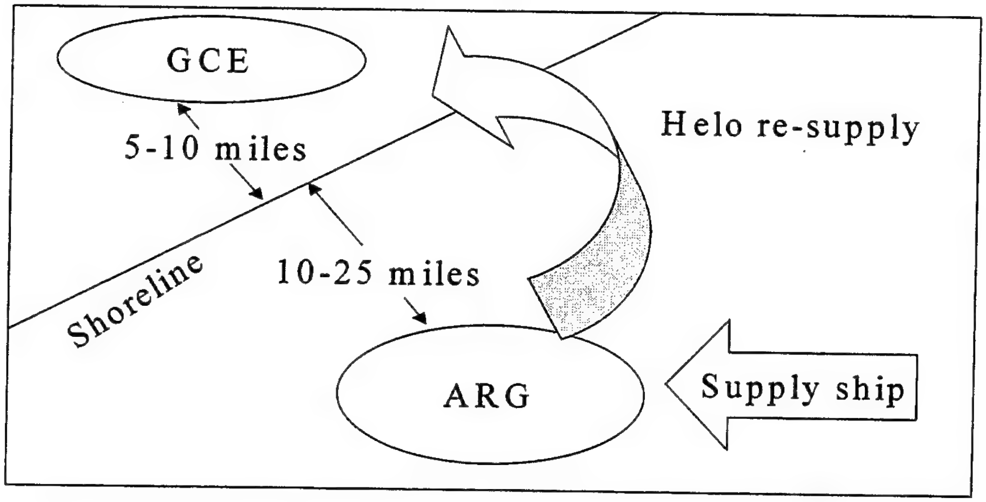

Figure 3. Scenario Overview

Aviation, Command and Control, and Logistics support (with the exception of the MCSSD) remained sea-based aboard the LHD. The landing force maintains two days of supply (DOS) within the MCCSD and requests a re-supply when they reach one DOS. By the end of the day they will reach the one DOS re-order point and will require a re-supply within twenty-four hours. The LHD had deployed with 15 DOS. The landing force has used eight DOS to date. The LHD is receiving an UNREP today of ten DOS to replenish its stocks. This re-supply consists of the palletized types of supplies listed in Table1.

Pallet Type	Description	# of Pallets
1	MRE	79
2	Ammunition	68
3	Misc.	79

Table 1. Pallet Types.

The supplies listed above are aboard a supply ship that has just arrived on station. VERTREP operations will transfer the cargo to the LHD. This process must be completed as quickly as possible because the LHD cannot perform normal flight operations in support of the ground forces until the UNREP operations on the flight deck

and hangar bay are completed. The ship will not return to full flight operation capability until all cargo is cleared from the flight deck and hangar bay. Two CH-46's from the supply ship will conduct the VERTREP.

Once the UNREP process is complete the re-supply of the landing force will commence. Two DOS of each type of cargo will be moved up from its stored position in the holds and unit stow area. It will be staged on the flight deck and prepared for helicopter transport to the landing force ashore.

C. MODELING APPROACH

This section details the integration of the scenario into the creation of the simulation model. We describe in detail the methodology, which defines the model scope, and assumptions used in developing the model. We then describe the data collected, and how it was assigned to the resources used in the model. This sets the stage for the next section, which describes our simulation approach.

1. Model Scope

We limit our scope to the inter/intra ship and ship-to-objective materiel movement in an OMFTS scenario, and therefore start with the transfer of a pre-determined quantity of supplies from a supply ship to a SBL platform, continue the movement within the platform and end with the movement of supplies to the objective ashore. We exclude the assembly and pre-staging of palletized cargo aboard the supply ship and assume this has already occurred. We do not consider weather effects, sea-state conditions or personnel and equipment casualties.

To meet the objectives for this thesis, we limit the model to the following elements:

- a pre-determined number of cargo types
- one supply ship and one receiving ship
- two CH-46 helicopters
- a pool of nine 6k forklifts and eight 4k forklifts
- three cargo and one deck-edge elevators aboard the receiving ship

2. Conceptual Model

The scenario developed for this model places a notional MAGTF ashore, operating in sustained combat type conditions. The primary purpose of this scenario is to generate demand for re-supply from the sea based MSSG aboard Amphibious Readiness Group (ARG) shipping using the SBL concepts. These represented the demand-based inputs shown in the conceptual model depicted in Figure 4. Using the current force structure and capabilities of an ARG/ MEU, we estimated the landing force daily sustainment rate for Class I, (Meal, Ready to Eat, (MRE)) and Class V (w) ground ammunition. Additionally we combined things like lumber, repair parts and other supplies into a third category labeled Miscellaneous. These daily sustainment requirements were then translated into pallet requirements for each type of cargo as shown in Table 1. These calculations are described in detail in Appendix A.

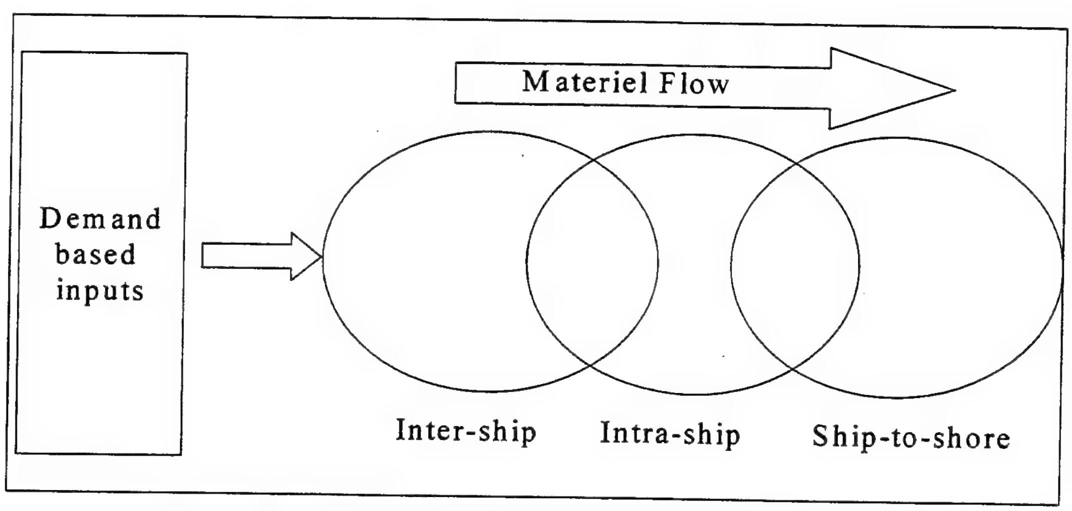

Figure 4. Conceptual Model.

We decided to limit the re-supply effort to these three classifications of supplies for several reasons. First, the supply types we chose represent some of the bulkiest and most mission-critical. Bulk liquids like fuel and water are also very bulky and critical, but were omitted because we wanted to concentrate on the flow of palletized loads through the system. MRE's, ammunition and the miscellaneous type provide a sufficient sample size to exercise the system, while keeping the model relatively simple. At the same time, they provide enough complexity to exercise and represent the inter/intra ship materiel movement system. Second, each type of pallet chosen has different characteristics and once aboard the receiving ship, takes a different path and utilizes different materiel handling equipment. The combined mix of pallet types provides an overall representation of the types of supplies that would actually be needed by a MEU sized MAGTF operating in a situation like we present in this chapter, and are summarized in Table 2.

Pallet Type	Description	# of Pallets	Wt in lbs/pallet	Destination	Elevator
1	MRE	79	918	Hold # 9	#5
2	Ammunition	68	2200	50% Hold #4 Lower 50% Hold #5 Lower	#1 #3
3	Misc.	79	1500	Upper Vehicle	N/A

Table 2. Pallet Type Summary.

Having the palletized cargo as input to the model, we chose to place it aboard a supply ship that is on station to re-supply the MEU. This began the inter-ship phase of our model. From the supply ship the palletized cargo was moved to the receiving ship, the LHD in our scenario, by two CH-46 helicopters. A key assumption at this point was made to have only these three types of pallets moved to the ship. In reality, the UNREP would include other landing force supplies, and possibly ships provisions and stores.

The rate of transfer used in our model was 20 lifts per hour. Since we were using minutes as our unit of time in this model this translated into one lift every three minutes on average. This planning factor was taken from [Ref. 10].

Since the SBL platform has yet to be defined in concrete terms, we needed a known capability to model as our starting point. An LHD was selected as the sea-based platform to be modeled in this scenario. In choosing the LHD we asked the following question; which current amphibious ship would provide the best ability to support OMFTS in terms of SBL if we had to do it today? The LHD/LHA classes of ships were determined to possess the best capability, capacity and flexibility to accomplish this. They each possess approximately the same capability, however, the LHD was ultimately chosen because it is newer, and the author was more familiar with it. The intent of simulating the LHD was not to suggest that a LHD be the SBL platform, but to represent a platform with LHD-like capabilities as a base model rather than an LHD itself. Estimated movement times for elevators and forklifts were gathered from interviews with personnel familiar with combat cargo operations.

[Ref. 12] and [Ref. 13], which included detailed deck diagrams, were used to discern the relative location of the various forklifts, elevators and holds. The model assumes that there is enough room to accommodate all of the oncoming supplies in the chosen holds. The holds chosen and the elevators that access them are listed in Table 2. We used the normal underway storage locations listed in [Ref. 12] for the initial allocation and placement of available forklifts as shown in Table 3. Ten additional 4k forklifts were distributed throughout the holds and magazines [Ref. 12]. The model assumes that these ten forklifts were available for use in the chosen holds.

Resource	Quantity
Flight Deck 4ks	4
Flight Deck 6ks	6
Hangar Bay 4ks	3
Hangar Bay 6ks	3

Table 3. Forklift Allocation.

Once the pallets arrived on the flight deck of the LHD, they were disconnected from the CH-46. Then a 4k forklift picked them up and traveled to either a cargo elevator or one of the deck edge elevators (aircraft elevators) [Ref. 14]. This began the intra-ship phase of the model. The pallet flow is depicted in Figures 5a, 5b and 5c.

Ammunition pallets vary greatly in size, hazard classification and weight, dependant on the type of ammunition. To simplify the simulation and still provide a meaningful level of detail for analysis, we decided to split the ammunition pallets into two hazard classifications based on estimated percentages for one day of ammunition (DOA) for a typical MEU sized MAGTF. [Ref. 15] Each group represented ammunition of similar hazard classes, and was moved to separate holds.

Type-2 Pallets destined for holds number 4 or 5 were loaded on cargo elevators 1 or 3 respectively, at flight deck level. They could also be lowered on the deck edge elevator and moved by 6K forklifts down the ramp to cargo elevators 1 or 2 on the third deck. However, we decided to only utilize the flight deck access to Elevators 1 and 3 to minimize the ammunition handling process.

In our model, type-1 and type-3 pallets were transported from the flight deck and placed on the deck edge elevator. This process was estimated to take one minute [Ref. 14]. Once a batch of 20 pallets accumulated on the elevator, the elevator was lowered to the hangar bay. This movement was estimated to take two minutes. [Ref. 16] Forklifts

then moved the pallets from the deck edge elevator to a staging area in the hangar bay. The process for each pallet was estimated to take one minute. [Ref. 14] Once the elevator was empty it returned to the flight deck.

From this staging area in the hangar bay, type-1 pallets took an estimated two minutes per pallet [Ref. 16] to move to elevator number 5 and were then lowered to hold number 9. All three cargo elevators used in the baseline model were estimated to take no more than two minutes to travel between decks. [Ref. 16] Additionally, all three cargo elevators accommodated four pallets at one time with a limit of 12,000 pounds [Ref. 12].

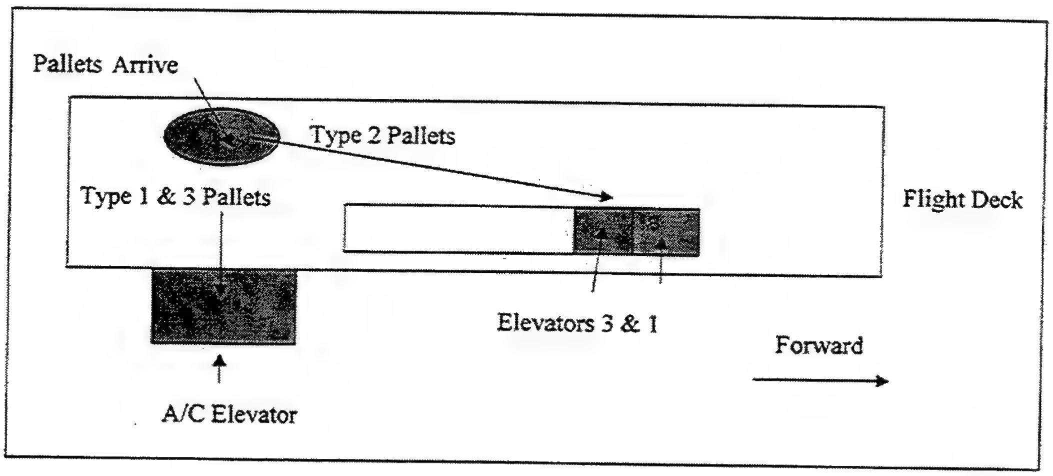

Figure 5a. Pallet Flow (Flight Deck).

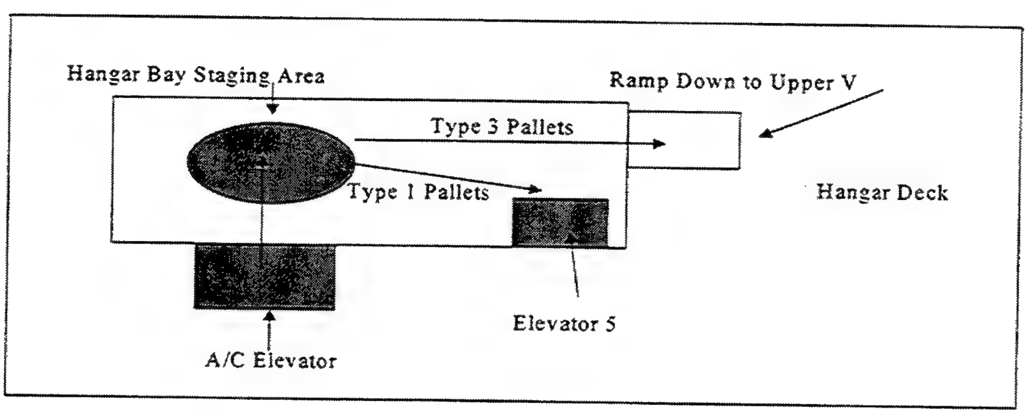

Figure 5b. Pallet Flow (Hangar Deck).

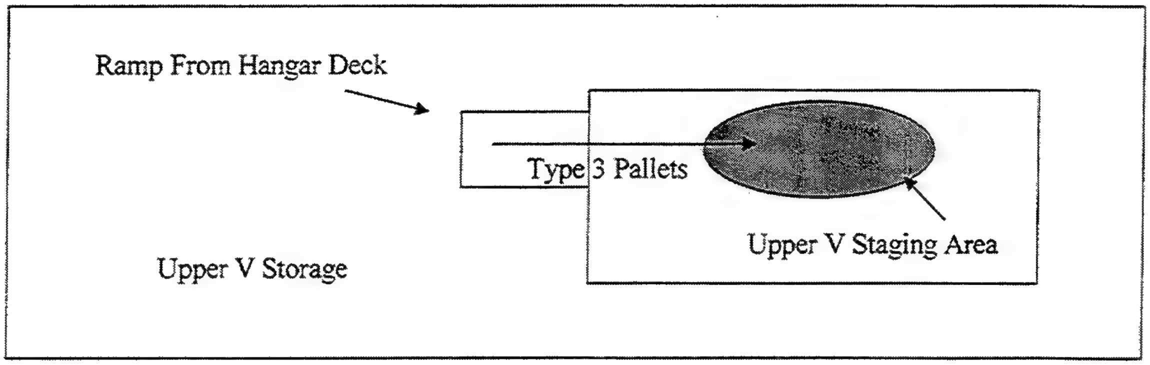

Figure 5c. Pallet Flow (Upper V).

Type-3 pallets took an estimated five minutes to move by 6k forklifts to the upper vehicle storage area (3rd deck) [Ref. 14]. These pallets were then broken down and stowed in Landing Force containers and spaces. The 6k forklifts were the only forklifts capable of moving pallets up and down the ramps between decks. Completion of this process signaled the end of the intra-ship phase of the model.

Conceptually, the third phase, ship-to-objective movement, can begin while either of the previous two phases are occurring. We assume, however that the flight deck and hangar bay would be too cluttered with pallets, personnel, debris and MHE to execute normal flight operations during the first two phases. Thus, we decided to start the ship-to-objective movement phase after all cargo reached its final destination.

The ship-to-objective movement phase begins with the supplies required by the landing force ashore being brought up from where they were stowed, to the flight deck for onward movement. In our baseline model, the demand from the landing force was 16 pallets of each type of supply representing approximately 2 DOS. We assumed these pallets would travel essentially in reverse, along the same routes described above. Once they reached the flight deck, they were flown ashore by landing force CH-53 helicopters. Using planning factors extracted from [Ref. 1] we estimated the CH-53 could carry four

pallets with a total weight of 10,000 lbs. It was estimated that the CH-53 could go from the LHD to the objective ashore, roughly 50 nautical miles, in 30 minutes. Our model does not take into consideration tactical limitations, enemy fire, or weather effects. It also assumes that once a Ch-53 is loaded it flies directly to the landing force. Once ashore, the pallets were received by the MCSSD. This ends the ship-to-objective movement phase.

D. SIMULATION APPROACH

Having developed the model, we then translated the model boundaries, processes and input data into a simulation model using the ARENA® software package.

1. Entities

Entities are dynamic objects that move around, change status, affect or are affected by the state of the system, and affect the output performance measures [Ref. 11]. The baseline simulation required three entities to represent the three pallet types listed previously in Table 1.

2. Attributes

For our baseline simulation, two attributes were assigned to each entity when they were created. To differentiate the pallet types throughout the system, we assigned the attribute, *type*. A value of 1, 2, and 3 was assigned to each type. We also assigned the attribute *amount* to each of the three entities, with a value representing the total number of each type. As the entities were "flown" to the LHD the amount was deducted from the current amount attribute's value by the value listed in Table 4.

Pallet Type	Attribute value
1	amount-3
2	amount-1
3	amount-2

Table 4. Attribute Value.

As the pallets left the supply ship they were deducted by the corresponding amount listed for each pallet type in Table 4 from the total value assigned previously to the amount attribute. This process continued until the total amount value reached zero.

3. Resources

Forklifts, elevators, the flight decks, and helicopters were represented in this simulation by assigning them as RESOURCES or TRANSPORTERS. The RESOURCES and TRANSPORTERS used in the baseline model are listed below in Table 5.

Resource	Quantity	Resource type
Elevator 1	1	Transporter
Elevator 3	1	Transporter
Elevator 5	1	Transporter
Elevator AC	1	Transporter
Flight Deck 4ks	4	Resource
Flight Deck 6ks	6	Resource
Hangar Bay 4ks	3	Resource
Hangar Bay 6ks	3	Resource
LHD Flight Deck	1	Resource
Supply Ship Flight Deck	1	Resource

Table 5. Resource/Transporter Matrix.

a. Forklifts

The forklifts on the flight deck and hangar bay level were pooled into three resource SETS; *flight deck forklifts*, *hangar bay 6ks* and *hangar bay 4ks*. Each one of these sets represented the number of forklifts by type, available on the LHD flight deck and hangar bay. When an entity required the use of a resource it SEIZED the resource. The resource then provided a forklift from the resource set. If no forklifts were available, the entity waited until a forklift within the set became available. For example, to move a pallet from the hangar bay staging area to elevator 5, the pallet SEIZED the resource set, Hangar bay 4k and 6k. Once an available forklift was SEIZED the pallet was routed to

elevator 5. Once this was completed the entity RELEASED the forklift. After another DELAY, representing the time it took the forklift to return to the staging area, the forklift was then available to move another pallet.

b. Elevators

Similarly, the TRANSPORTER module was used to simulate the elevator movements. To use the TRANSPORTER module, STATIONS were defined identifying the entrance to the elevators and the destinations of the elevators. STATIONS simulated physical locations throughout the model. All STATIONS and their corresponding locations are summarized in Table 6.

Station Name	Physical Location
LHD	LHD
LHD Flight Deck	LHD Flight Deck
Supply Ship	Supply Ship Flight Deck
supply Ship entry	CH-46 Holding area
AC Elevator	Starboard deck edge elevator
Elevator 1	Entry to Elevator 1 on LHD Flight deck
Elevator 2	Entry to Elevator 3 on LHD Flight deck
Elevator 3	Entry to Elevator 5 on LHD Hangar deck
Hold 4 lower	Hold 4 lower
Hold 5 lower	Hold 5 lower
Hold 9	Hold 9
Landing Force	Landing Force Ashore

Table 6. Stations.

Once STATIONS were defined, each elevator was assigned a DISTANCE block (distance between a pair of stations) to simulate the time it took the elevators to travel to their respective destinations. We estimated a two-minute travel time for the three cargo elevators. A velocity of one was then assigned within the TRANSPORTER module. Thus, the elevators traveled two units with a velocity of one unit. Since the baseline simulation used minutes as units, the elevators moved at a velocity of one unit

over a distance of two units (i.e., two minutes). The same logic was applied to the aircraft elevator using a distance of three units and a velocity of one unit.

c. Flight Decks

The baseline simulation assumed the flight decks of the supply ship and LHD could only accommodate one helicopter at a time to load or unload pallets. In order to allow only one helicopter at a time to occupy the flight decks, each flight deck was assigned as a RESOURCE. Once the helicopters occupied (using SIEZE) the flight deck they were DELAYED one minute to simulate the process of approaching, hovering while picking up or dropping off pallets and then departing. They then RELEASED the flight deck RESOURCE. Once the flight deck was RELEASED, another helicopter could seize it. The model assumed that the staging areas and receiving areas on the flight decks are unconstrained.

d. Helicopters

Two CH-46 helicopters and two CH-53 helicopters were assigned as entities in the baseline simulation. Each type of helicopter was assigned as a single entity with a capacity of two.

4. Queues

Queues provide a place for an entity to wait until a resource becomes available. Queues were useful in this simulation to identify any constraints in the materiel movement flow.

5. Events

An event is "something that happens at an instant of simulated time that might change attributes, variables or statistical accumulators." [Ref. 11] In order to realistically represent the model developed in previous sections of this chapter, the following procedures were designated as required events for the simulation:

- creation of three types pallets aboard the supply ship
- movement of the pallets to the LHD
- arrival of pallets aboard LHD
- movement of pallets to their destinations aboard the LHD
- designated number of pallets for movement to shore based objective
- movement of pallets to shore based objective
- end of simulation occurs when final pallet reaches the destination

The baseline simulation clock started at time zero. At this time the supply ship was on station and ready for the first movement. The pallets now started their journey through the system. Once a pallet arrived on the flight deck, the model forwarded the pallet to its designated path through the system. Each pallet type flowed through the system in the following manner:

a. Pallet Type-1 Flow

Type-1 represented MRE pallets destined for Hold 9. Once the model identified the pallet as type-1 it SEIZED a forklift from the flight deck 4k and 6k RESOURCE SET. The pallet was then ROUTED to the AC elevator. The pallets were BATCHED in groups of 20. After 20 pallets were on the AC elevator the elevator moved to the Hangar deck. The pallets then SEIZED a forklift from the hangar bay 4k and 6k resource set. After a DELAY of 15 seconds simulating the loading, movement and unloading times they were ROUTED to the hangar bay staging area. Once all 20 pallets were moved from the elevator to the staging area in this manner, the AC elevator was RELEASED and returned to the flight deck. Once in the staging area, and the model identified the pallet as type-1, the pallet SEIZED a forklift. It was then routed with a Uniform (1,2) minute travel time to elevator 5. The pallet was now on the elevator. After a DELAY of one minute for unloading, the pallet RELEASED the forklift to return to the staging area. The forklift was now ready to load another pallet at the staging area. Since

elevator 5 had a four-pallet capacity, pallets were BATCHED in groups of four. Once four pallets were on the elevator they were TRANSPORTED to the station hold 9. After a DELAY of one minute, representing offloading time, the pallets DEPART the system. This represented the pallets' final destination.

b. Pallet Type-2 Flow

Type-2 pallets represented ammunition pallets. As the pallet arrived it SEIZED a forklift from the flight deck RESOURCE pool. Once the model identified the pallet as type-2, 50 percent of type-2 pallets were randomly ROUTED with travel times of Uniform (1,2) minutes to elevator 1 and 50 percent with travel times of Uniform (1,2) minutes to elevator 3, which were accessed at flight deck level. A DELAY of one minute was then required to simulate the time before the forklift could be used again. The forklift was then RELEASED and immediately picked up the next pallet if there was one to be moved. Once the pallets were on their respective elevators the process was the same as described above for pallet type-1, the only difference being the elevators and final destinations of the pallets. The pallets then DEPART the system.

c. Pallet Type-3 Flow

Type-3 pallets represented miscellaneous supplies. Type-3 pallets flowed from the flight deck to the hangar bay staging area exactly like type-1 pallets. From the hangar bay staging area, type 3 pallets SEIZED one of the hangar bay 6k forklifts and were ROUTED to the station, Upper V Storage, with an estimated Uniform (4,6) minutes for the forklifts' travel time. After a DELAY of Uniform (4,6) minutes the forklift was RELEASED. This DELAY represented the travel time back to the staging area. An arbitrary estimate of a 30-minute DELAY was assigned representing the manual breakdown, processing and re-storage of the materiel on these pallets. Due to the

variability of this process, the value "EXPO (30)" (exponentially distributed with a mean of 30 minutes) was entered into this DELAY statement. This simulated the variability in the time it took to breakdown type-3 pallets. Finally type-3 pallets DEPART the system.

6. Statistics Collection

The time the LHD spends "connected" to the supply ship and the time the LHD spends conducting the entire UNREP process, keeps the ship from its primary mission of supporting the landing force. Therefore our primary performance metric was the overall cycle time of the system, starting with the time the first pallet left the supply ship to the time the last pallet was stored on the LHD. Our secondary performance metric was VERTREP cycle time, which represented the time it took to complete the UNREP portion of the model. By keeping track of these cycle times, we could assess the impact on cycle time of the modifications to the baseline model.

E. CHAPTER SUMMARY

In this chapter we first presented a scenario based on the tenets of the OMFTS and SBL concepts. We then detailed the methodology used to develop our model. Finally we integrated the conceptual model into a simulation model. The simulation model presented in this chapter provided a baseline model for experimentation and analysis in Chapter IV.

IV. EXPERIMENTATION AND ANALYSIS

A. OVERVIEW

A key aspect of simulation modeling is the verification, validation and experimentation process. Verification is the process that ensures the model behaves as you desire. This process is also referred to as "debugging". Validation ensures the model behaves in the simulation as it would in the real world. Experimentation allows you to modify the model to assess the impact of the modification on the system's performance. [Ref. 11]

To verify the model, we simply ensured that the proper amount of pallets ended up at their proper destination. Since the model incorporated both current inter/intra ship materiel movement capabilities and future concepts, it was impossible to validate the model without actually conducting a real world experiment. Therefore we validated the portions of the model we could with the planning factors and time estimates described in Chapter III.

B. BASELINE SIMULATION

The purpose of our simulation was to gain insight on materiel movement processes to further the development of the SBL concept. To accomplish this we decided to focus on the total cycle time of the inter/intra ship process and the UNREP cycle time. We set up the Arena® STATISTICS module to keep track of the total cycle time (TNOW in our model). We assigned the VARIABLE (MAX (END OF VERTREP (i)) (i= 1,2,3 where i is the type of pallet) to gather UNREP cycle time statistics during the simulation. UNREP cycle time is important because the process is risky for several reasons. Operating large ships in close proximity is inherently risky. During the UNREP process

the ships typically slow down, decreasing the flexibility of maneuver. They are also more vulnerable to enemy attack. Therefore decreasing UNREP cycle time reduces risk.

To produce a sufficient sample size for meaningful statistical analysis we ran the simulation for 30 replications. The system and statistics were set to initialize at the start of each replication. The total inter/intra ship cycle time and UNREP cycle time for each replication was averaged over the 30 replications and recorded in the Output Summary shown in Figure 6. Additionally, the Output Summary recorded the average half-width minimum and maximum times observed over the 30 replications.

Output Summary for 30 Replications/BASE MODEL

Project: SBL Model
Analyst: MJ Curtin

Run execution date : 6/ 5/2001
Model revision date: 2001/ 6/1904

OUTPUTS

Identifier	Average	½ width	Min	Max	# Replications
TNOW	396.12	11.213	349.85	478.75	30
MAX(END OF VERTREP(1),	299.79	1.4321	291.62	307.08	30
END OF VERTREP(1)	174.70	.93311	169.68	180.24	30
END OF VERTREP(2)	299.79	1.4321	291.62	307.08	30
END OF VERTREP(3)	237.00	1.1729	229.88	243.80	30

Figure 6. Sample Arena® Output Summary.

The baseline simulation resulted in a total cycle time (TNOW) of 396.12 minutes (6.6 hours). This represented the time from the first pallet departing the supply ship until the last pallet was stowed on the LHD. The total UNREP cycle time (MAX (END OF

VERTREP (i)) was 299.79 minutes (5 hours). This was how long it took for all pallets to depart the supply ship. The difference between the total cycle time and the UNREP cycle time was 96 minutes. After the last pallet left the supply ship it took an additional 96 minutes before the last pallet was stowed in the receiving ship.

Also recorded were the UNREP cycle times for each pallet type (END OF VERTREP (i)). These times mark the time in the process that the last pallet of each type was free of the supply ship, as shown in Figure 5. These results indicate that the UNREP of type-1 pallets was completed first, type-3 second and finally type 2. Recall that due to the weights of the individual pallets, type-1 pallets were moved three at a time, type-3 pallets were moved two at a time and type-2 pallets were moved one at a time. Thus, the order in which the three pallet types completed the VERTREP process is explained by the relationship between the individual pallet weights and the lift capacity of the CH-46.

Additionally, the ship-to-objective phase of the model was run with two Ch-53 helicopters and then again with four Ch-53 helicopters. The cycle time of this phase was recorded in the same way as in the other two phases. The additional two helicopters reduced cycle time by 49 percent. This was linearly proportionate to the increase in the number of helicopters since the travel time had little variability. The model output also indicated a small bottleneck in the cargo elevators. This was due to the fact that no pre-staging of pallets on the flight deck was done. In reality, pallets would be pre-staged prior to the actual mission. Therefore a bottleneck with the cargo elevators may not be a factor. This does suggest however, that in a scenario with increased demand of re – supply materiel from a larger landing force, the cargo elevators may become a system

limitation if continuous throughput of materiel from the holds to the flight deck is required.

C. EXPERIMENTATION

Reducing overall cycle time is very important during materiel transfer. Recall in our model that the LHD was not able to conduct full flight operations in support of the landing force until the flight deck and hangar bay were clear of pallets and debris. The quicker the transfer and stowage of materiel, the quicker the ship could resume its warfighting functions to include re-supplying the landing force. Conducting UNREP operations also limits the mobility and flexibility of the LHD, since the ship needs to remain "connected" (either physically for a CONREP, or as in our model, in close proximity to the supply ship for a VERTREP). The following experiments were conducted to assess what impact the modifications had on these cycle times.

1. Modification One

Overall cycle time for the baseline simulation was 396 minutes and UNREP cycle time was 300 minutes. We asked the question, "What is the impact on the overall and UNREP cycle times if we vary the number of CH-46s used during the UNREP?" Keeping all other conditions and assumptions from the baseline model the same we varied the number of CH-46s used for VERTREP from one to four. Additionally we assumed that up to four helicopters could be used without the helicopters getting in the way of each other. The outputs of this experiment are listed in Appendix B and summarized in Figure 7.

The results of this experiment indicated that as the number of helicopters increased the total cycle time decreased. However the most significant decrease of approximately 35 percent was experienced from the addition of one helicopter to two.

Cycle time decreased by a total of 22 minutes from the addition of the third and fourth additional helicopter. Total cycle time decreased 11 minutes with the addition of a third helicopter. The addition of the fourth helicopter decreased the total cycle time by an additional 11 minutes.

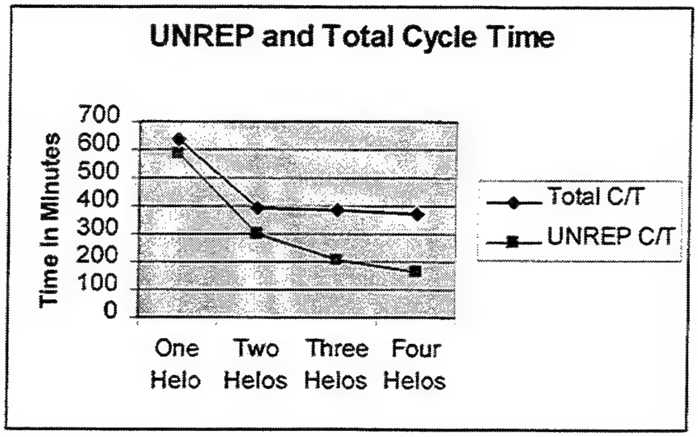

Figure 7. UNREP and Total Cycle Times.

Similarly, the largest decrease in UNREP cycle time came after the addition of the second helicopter. This was a decrease of approximately 45 percent. The addition of the third and fourth helicopters decreased the UNREP cycle time by a total of 104 minutes. The decrease between the second and third additional helicopter was 94 minutes while the decrease for the fourth helicopter was 44 minutes.

These results indicate that total cycle time is only marginally reduced with the addition of the third and fourth helicopters to conduct the UNREP. UNREP cycle time however, is significantly reduced with these additions. By increasing the number of resources used to transfer materiel between ships the two ships can spend less time "connected". However the total cycle time with the additional resources means the pallets move to the LHD very quickly and accumulate on the flight deck in large numbers

before they can be processed through the ship. The difference between the total cycle times and UNREP cycle times inferred a constraint within the intra-ship materiel movement process. This also suggested that if the priority for the LHD was to minimize the time spent "connected" to the supply ship, then the additional helicopters would be valuable. If the priority was to reduce total cycle time, then the additional helicopter offered no significant value.

2. Modification Two

Our second experiment addresses the question "what is the impact on the total and UNREP cycle times of increasing the lift capacity of the CH-46?" The baseline model was modified to simulate the increased capacity of the resource identified in our model as the CH-46 helicopter. We do not wish to imply that in reality the CH-46 has the capability or potential to lift the increased weight. We are simply using the simulation to quantify the impact on cycle time of the increased lift capability during the inter–ship materiel movement process. The results may also provide insight into future helicopter design.

The lift capability was modified in the Arena® simulation logic by increasing the number of pallets deducted from the amount attribute. Recall that in the baseline model three type-1 pallets, one type-2 pallets and two type-3 pallets were moved at one time respectively by the CH-46s. This assumed a 3,000-pound lift capability for the CH-46. For this experiment we doubled, tripled and quadrupled the lift capacity for the CH-46. This corresponds to 6,000, 9,000 and 12,000 pound lift capabilities for the CH-46 in our model. This modification assumed that the supplies were configured in pallet form as in the baseline model. It was assumed that the helicopter could transfer the number of pallets representing the increased weight capability for each trip. For example, type-3

pallets weighing 1,500 pounds each were moved two at a time for the baseline simulation, four at a time for the 6,000-pound capability simulation and so forth.

As in the first experiment, we were interested in the total and UNREP cycle times. Keeping all other conditions and assumptions from the baseline model the same we ran the simulation. The output summary shown in Appendix C lists the results of this experiment and is summarized in Figure 8.

Doubling the lift capacity of the helicopters to 6,000 pounds reduced total cycle time from the baseline model by 34 percent (134 minutes) and UNREP cycle time by 50 percent (151 minutes). Tripling the lift capacity to 9,000 pounds reduced total cycle time by 56 percent (220 minutes) and UNREP cycle time by 66 percent (200 minutes). Quadrupling the lift capacity to 12,000 lbs reduced total cycle time by 48 percent (190 minutes) and UNREP cycle time by 75 percent (226 minutes).

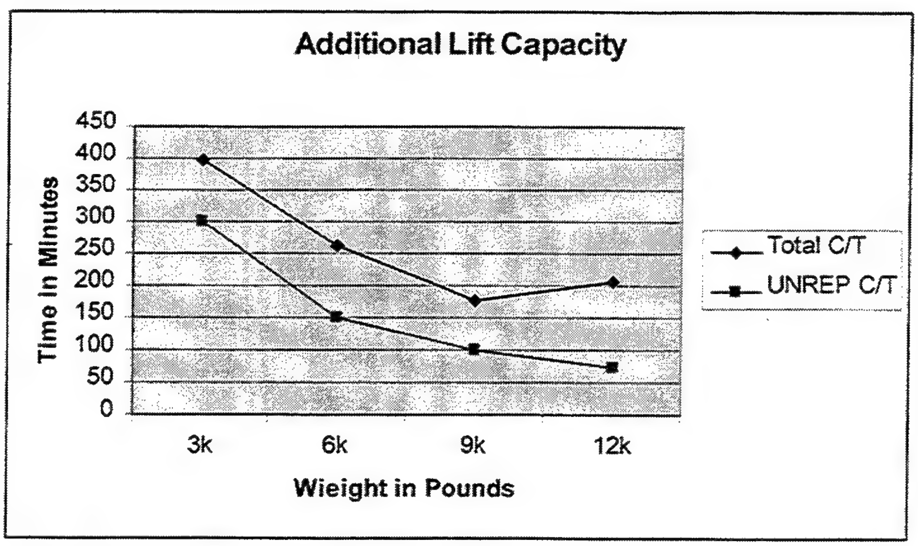

Figure 8. Experiment Two Results

Total cycle time was reduced significantly between the 3,000 pound and 9,000 pound capacities. However there was a slight increase in total cycle time between the

9,000-pound capacity and the 12,000-pound capacity. This suggests that there is a limitation within the intra-ship materiel movement process aboard the LHD. With the increased lift capacity, pallets were shuttled to the LHD much faster. This meant that a greater number of pallets were assembled on the LHD flight deck awaiting transport to their final destinations. Since the model was designed to move pallets through the system the sheer number of pallets awaiting transport on the LHD flight deck caused a bottleneck due to resource limitations, thus increasing the total cycle time. Even with this slight increase the total cycle time was significantly reduced from the baseline simulation by 48 percent.

Overall, UNREP cycle time was reduced by 75 percent. A 50 percent reduction occurred between the 3,000 and 6,000 pound capacities. Significant reductions of 33 percent and 26 percent were realized between the 6,000-9,000 pound capacity and 9,000-12,000 capacities, respectively. This suggests that the additional capacity has a significant impact on the UNREP cycle times.

These results suggest that by increasing the lift capacity of the helicopters conducting the VERTREP, significant reductions in cycle times are achieved. The time the LHD has to spend "connected" to the supply ship and away from its primary mission is greatly reduced.

D. SUMMARY

This chapter first explained the verification and validation of our baseline simulation model. We then conducted and analyzed two experiments by modifying the baseline model to see the impact on cycle times. The next chapter provides our conclusions, recommendations and areas for further study.

V. CONCLUSIONS AND RECOMMENDATIONS

A. INTRODUCTION

The concept of Sea Based Logistics is an area rich with opportunities for research. Since the sea base platform has yet to be defined, any research offering insight into its design is potentially valuable. The more time that is invested in research, development and evaluation of this concept up front, the better the end product will be for the future generation of Marines and Sailors who will actually operate under it. This chapter summarizes our conclusions, recommendations and areas for further research into the concept of Sea Based Logistics.

B. CONCLUSIONS

1. Increased Lift Capacity for Inter-Ship Materiel Movement

Increasing the lift capacity of the helicopter conducting the UNREP in our model significantly reduced the total cycle time and UNREP cycle time of the inter/intra ship materiel movement process. Increasing the lift capacity of the CH-46 helicopter to 12,000 pounds is unrealistic. However, increased lift should be considered in the design of future helicopters. We found raising the lift capacity of the helicopter conducting the UNREP operations from 3,000 pounds to 12,000 pounds decreased total cycle time by 48 percent and decreased the UNREP cycle time by 75 percent. This reduction in cycle time is linearly proportional to the increase in lift capacity since the travel time (including loading and unloading times) had little variability. Other external factors not considered in this simulation, such as, weather, sea-state and enemy action would also affect the simulation results. Reducing the UNREP cycle time reduces the risks involved with

UNREP operations such as collisions and vulnerability to enemy attack. Additionally, UNREP operations limit flight operations on LHD-like ships.

The time the LHD spends receiving and stowing landing force supplies decreases the ship's capability to support forces ashore in terms of close air support, helicopter assault support and logistical support. The quicker the ship can complete UNREP operations, the quicker it can resume these essential functions. This is extremely important in OMFTS operations. Forces ashore relying on sea based logistical support will be operating with minimal safety stocks. Receiving needed supplies on a timely basis will be critical. If the sea based logistics platform is busy performing UNREP operations, its capability to support forces ashore is diminished. Therefore, minimizing the time spent replenishing amphibious ships increases their ability to support the forces ashore.

2. Impact of Increasing the Number of Helicopters used for UNREP

Increasing the number of helicopters used to conduct UNREP operations in our model only marginally decreased total cycle time. The increase from two to four CH-46 helicopters only decreased total cycle time by an average of 22 minutes. However the increase to four helicopters reduced UNREP cycle time by 47 percent. Increasing the number of helicopters would only be of benefit if the mission priority was focused on completing the UNREP portion of the process. Essentially the pallets were "dumped" aboard the LHD flight deck very quickly. As the number of pallets awaiting movement from the flight deck increased, the utilization rate of the three cargo elevators also increased. This suggested that the cargo elevators were a bottleneck and could not move the pallets to their final destination at the same rate the pallets were received on the LHD.

During the ship-to-objective phase of the model, increasing the number of CH-53 helicopters from two to four decreased the ship-to-objective cycle time by 49 percent. This reduction in cycle time is also linearly proportionate to the increase in lift capacity since the travel time had little variability and there were no operational constraints put into the scenario.

3. Simulation Modeling

Simulation models are used to gain insight on how systems behave. They are especially effective in representing complex real-world systems that currently exist. Simulation models can be used to experiment with proposed systems. In this manner, simulation models can shed light on the behavior of the future systems or concepts that have yet to be designed. This is especially useful because any number of "what-if" type experiments can be performed to gain insight into the future system's performance. Our model was designed with this in mind.

We developed our model for use as a tool to gain insight into the concepts of OMFTS and SBL. The model represents aspects of our current inter/intra ship materiel movement capability blended into a scenario based on the above-mentioned concepts. Much time was spent on the design of the model in order to provide future researchers a tool to gain insight into the complex task of designing the sea based logistics platform that will support the concept of OMFTS.

B. RECOMMENDATIONS

1. Increased Lift Capacity for Inter-Ship Materiel Movement

We recommend exploration into the development of a capability to increase the lift capacity during transfer of materiel from ship to ship. Our model focused on vertical replenishment by helicopter, however methods for connected replenishment should also

be considered. Our simulation model represented the cargo moving by pallets. In modification two, when we quadrupled the lift capacity of the helicopter to 12,000 lbs, the number of type-1 pallets being transferred was 12. Twelve individual pallets externally loaded and moved at one time seemed unrealistic. Further research into how cargo is packaged for movement is therefore recommended.

2. Impact of Increasing the Number of Helicopters Used for UNREP

Using more than two helicopters for vertical replenishment appeared to have minimal impact on reducing cycle time. However, further research into the impact on cycle time of running multiple cargo receiving stations aboard the sea based logistics platform is recommended. Additionally, further study into the placement and composition of elevators, storage areas and materiel handling resources aboard the sea base platform is recommended.

Additionally, further research into the conduct of the ship-to-objective movement phase is recommended. Tactical, operational and environmental considerations should be considered and incorporated into the model.

3. Simulation Modeling

The experiments conducted in this thesis were limited to assessing the impacts on cycle time by modifying only two variables. However, there is great potential for further experimentation into the subject of sea based logistics utilizing this model or one like it. This model was developed for modification and expansion as needed. Further research and opportunities to expand and refine the model include, but are not limited to the following:

- incorporating the impact of environmental effects on operations
- modeling the ship to objective phase of the model

- assessing the impact of larger quantities of cargo through the system
- introducing personnel and equipment casualties into the model
- assessing the impact of different types of palletization and containerization of cargo on the materiel movement process
- incorporating tactical considerations on ship-to-objective movement

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APPENDIX A. METHODOLOGY FOR ESTIMATING DAILY SUSTAINMENT REQUIREMENTS

A. METHODOLOGY

Type-1 pallets- Class I (MRE) requirements are a function of the number of people ashore. Daily MRE requirements were computed by first multiplying the total number of personnel ashore (1,500) by the planning factor of three meals per day. This figure, (4,500), was multiplied by the total DOS required (10). This resulted in the total number of meals needed for the required length of time (45,000). A pallet of MRE's contains 576 meals (48 cases of 12 meals per case). Dividing the total MRE requirement by 576 results in a total pallet requirement of 79 pallets.

Type-2 pallets-The number of Class V (w), ground ammunition pallets required for the landing force in our scenario were adapted from [Ref. 1]. [Ref. 1] lists the landing force daily sustainment requirements in short tons for a MEB sized unit of 6,806. Since our force was roughly 22 percent the size of the MEB sized unit, we multiplied the ammunition requirement for the MEB (33.48 short tons) by 22 percent. This came out to a daily requirement for our force of 7.3656 short tons per day. Multiplying this by ten gave us our ten-day gross requirement in short tons. After interviewing several people knowledgeable in the ammunition field, we estimated the average weight per ammunition pallet was roughly 2200 lbs. Dividing our gross requirement by the pallet weight resulted in a requirement for 68 pallets for the ten-day period.

Type-3 pallets- the number of type-3 pallets required was also adapted from [Ref. 1]. [Ref. 1] listed "other cargo" daily requirement of 26.54 short tons for a MEB-sized unit of 6,806. Taking 22% of 26.54 gave us a daily requirement for our scenario of

5.8388. We arbitrarily estimated the pallet weight of 1,500 lbs for type-3 pallets. Multiplying the daily requirement of 5.8388 by 10 and dividing by the average pallet weight of 1500lbs, gave us a gross requirement of 79 pallets.

APPENDIX B. ARENA OUTPUT SUMMARY FOR MODIFICATION NUMBER ONE

ARENA Simulation Results
NPS - License #9400000

Output Summary for 30 Replications/ ONE HELO

Project: SBL model
Analyst: MJ Curtin

Run execution date : 6/ 5/2001
Model revision date: 2001/ 6/1904

OUTPUTS

Identifier	Average	½ width	Min	Max	# Replications
TNOW	635.81	12.557	585.95	734.67	30
END OF VERTREP(3)	465.25	1.7471	452.53	473.91	30
MAX(END OF VERTREP(1),	587.63	2.1700	575.91	598.72	30
END OF VERTREP(2)	587.63	2.1700	575.91	598.72	30
END OF VERTREP(1)	342.60	1.3900	336.17	348.81	30

Output Summary for 30 Replications/BASE MODEL

Project: SBL Model
Analyst: MJ Curtin

Run execution date : 6/ 5/2001
Model revision date: 2001/ 6/1904

OUTPUTS

Identifier	Average	½ width	Min	Max	# Replications
TNOW	396.12	11.213	349.85	478.75	30
END OF VERTREP(3)	237.00	1.1729	229.88	243.80	30
MAX(END OF VERTREP(1),	299.79	1.4321	291.62	307.08	30
END OF VERTREP(2)	299.79	1.4321	291.62	307.08	30
END OF VERTREP(1)	174.70	.93311	169.68	180.24	30

Output Summary for 30 Replications/THREE HELOS

Project: SBL Model
Analyst: MJ Curtin

Run execution date : 6/ 5/2001
Model revision date: 2001/ 6/1904

OUTPUTS

Identifier	Average	½ width	Min	Max	# Replications
TNOW	385.11	12.414	317.04	455.01	30
END OF VERTREP(3)	161.40	.59027	158.99	164.17	30
MAX(END OF VERTREP(1),	204.09	.73705	201.22	208.14	30
END OF VERTREP(2)	204.09	.73705	201.22	208.14	30
END OF VERTREP(1)	119.16	.48395	116.91	122.22	30

Output Summary for 30 Replications/FOUR HELOS

Project: SBL Model
Analyst: MJ Curtin

Run execution date : 6/ 5/2001
Model revision date: 2001/ 6/1904

OUTPUTS

Identifier	Average	½ width	Min	Max	# Replications
TNOW	374.76	12.045	322.80	465.30	30
END OF VERTREP(3)	127.20	.60052	123.08	130.98	30
MAX(END OF VERTREP(1),	160.76	.67666	155.93	165.26	30
END OF VERTREP(2)	160.76	.67666	155.93	165.26	30
END OF VERTREP(1)	94.106	.42777	91.914	96.040	30

APPENDIX C. ARENA OUTPUT SUMMARY FOR MODIFICATION NUMBER TWO

ARENA Simulation Results
NPS - License #9400000

Output Summary for 30 Replications/ ONE HELO

Project: SBL model
Analyst: MJ Curtin

Run execution date : 6/ 5/2001
Model revision date: 2001/ 6/1904

OUTPUTS

Identifier	Average	½ width	Min	Max	# Replications
TNOW	635.81	12.557	585.95	734.67	30
END OF VERTREP(3)	465.25	1.7471	452.53	473.91	30
MAX(END OF VERTREP(1),	587.63	2.1700	575.91	598.72	30
END OF VERTREP(2)	587.63	2.1700	575.91	598.72	30
END OF VERTREP(1)	342.60	1.3900	336.17	348.81	30

Output Summary for 30 Replications/BASE MODEL

Project: SBL Model
Analyst: MJ Curtin

Run execution date : 6/ 5/2001
Model revision date: 2001/ 6/1904

OUTPUTS

Identifier	Average	½ width	Min	Max	# Replications
TNOW	396.12	11.213	349.85	478.75	30
END OF VERTREP(3)	237.00	1.1729	229.88	243.80	30
MAX(END OF VERTREP(1),	299.79	1.4321	291.62	307.08	30
END OF VERTREP(2)	299.79	1.4321	291.62	307.08	30
END OF VERTREP(1)	174.70	.93311	169.68	180.24	30

Output Summary for 30 Replications/THREE HELOS

Project: SBL Model
Analyst: MJ Curtin

Run execution date : 6/ 5/2001
Model revision date: 2001/ 6/1904

OUTPUTS

Identifier	Average	½ width	Min	Max	# Replications
TNOW	385.11	12.414	317.04	455.01	30
END OF VERTREP(3)	161.40	.59027	158.99	164.17	30
MAX(END OF VERTREP(1),	204.09	.73705	201.22	208.14	30
END OF VERTREP(2)	204.09	.73705	201.22	208.14	30
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END OF VERTREP(2)	160.76	.67666	155.93	165.26	30
END OF VERTREP(1)	94.106	.42777	91.914	96.040	30

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